

AMENDMENTS TO THE CLAIMS

All claims and their status are reflected below.

1. – 54. (cancelled)

55. (Previously presented) A method of measuring alignment accuracy between two or more patterned layers formed on a substrate comprising:

forming test areas as part of the patterned layers, wherein a first diffraction grating is built into a patterned layer A and a second diffraction grating is built into a patterned layer B, where layers A and B are desired to be aligned with respect to each other, zero or more layers of other materials separating layers A and B, the two gratings substantially overlapping when viewed from a direction that is perpendicular to the surfaces of A and B;

observing the overlaid diffraction gratings using an optical instrument capable of measuring reflectance as a function of wavelength or polarization of illumination and detection using the instrument, or capable of measuring ellipsometric parameters as a function of wavelength of the illumination and detection; and

determining the offset between the gratings from the measurements from the optical instrument using an optical model, wherein the optical model accounts for the diffraction of the electromagnetic waves by the gratings and [the interaction of the gratings with each other's diffracted field.

56. (Previously presented) The method of claim 55 wherein any layers between the grating in layer A and the grating in layer B are at least partially transparent at the wavelength range of the optical instrument.

57. (Previously presented) The method of claim 55 wherein at least one layer between the grating in layer A and the grating in layer B is opaque in the wavelength range of the optical instrument, and the presence of the grating in layer A causes a grating-shaped topography on the surface of the opaque layer.

58. (Previously presented) The method of claim 55 wherein the optical model represents the electromagnetic field in the gratings and in the layers between the gratings as a sum of more than one diffracted orders.

59. (Previously presented) The method of claim 55 wherein offset is determined by:
calculating, according to a model of a wafer sample, the optical response of the sample with said two overlapping gratings, the model of the sample taking into account parameters of the sample including any of the overlay misalignment of layers A and B, and a profile parameter of the grating structures; and
minimizing the difference between the calculated and measured optical responses

60. (Previously presented) The method of claim 59 wherein at least a portion of the calculated optical response is retrieved from a pre-computed database.

61. (Previously presented) The method of claim 55 wherein at least one of the two gratings contains more than one line per pitch, the widths of the at least two lines in each pitch (unit cell) being substantially different from each other.

62. (Previously presented) A method of measuring alignment accuracy between two or more patterned layers formed on a substrate comprising:
forming test areas as part of the patterned layers, wherein a first diffraction grating is built into a first patterned layer and a second diffraction grating is built into a second patterned layer, the two gratings substantially overlapping when viewed from a direction that is perpendicular to the surfaces of A and B, and at least one of the first or second gratings having a repeating pattern consisting of at least two structures of substantially different lateral dimensions;
measuring the optical characteristics of the overlaid diffraction gratings using an optical instrument with a spot size covering portions of the overlapping gratings; and
determining the offset between the gratings from the measured optical characteristics.

63. (Withdrawn) A method of determining a degree of registration between an upper layer and a lower layer formed on a substrate, each of said layers including a periodic structure formed thereon and arranged to at least partially overlap, said method comprising the steps of:
illuminating the layers with a probe beam of radiation;

monitoring the zeroth order light diffracted from the layers;
generating a parameterized model representing the geometry and registration of parameters of the model; and
comparing the predicted optical response with the monitored zeroth order light to determine the registration of the structures.

64. (Withdrawn) A method as recited in claim 63 wherein said generating step is at least partially carried out in advance for a number of different parameters and wherein the corresponding responses are stored in a database for later comparison with the monitored response.

65. (Withdrawn) A method as recited in claim 63 wherein said probe beam is generated from a broadband source and said monitoring step is carried out as function of wavelength.

66. (Withdrawn) An apparatus for determining overlay error between two or more patterned layers of a sample, comprising,

a metrology target comprising a first diffraction grating built into a patterned layer A and a second diffraction grating built into a patterned layer B, where layers A and B are part of the sample under test and layers A and B are desired to be aligned with respect to each other, the two gratings substantially overlapping when viewed from a direction that is perpendicular to the layers A and B;

an optical instrument that illuminates the metrology target and that measures properties of light that has interacted with the metrology target as a function of polarization of the illumination and detection; and

a processor which estimates the offset of the grating pair from the measured properties.

67. (Withdrawn) The apparatus of claim 66 wherein at least one of the two gratings contains more than one line per pitch, the widths of the at least two lines in each pitch (unit cell) being substantially different from each other.

68. (Withdrawn) The apparatus of claim 66 wherein at least one other layer of material separates layers A and B at the metrology target.

69. (Withdrawn) The apparatus of claim 66 wherein the optical instrument measures properties of light that has interacted with the metrology target as a function of wavelength.

70. (Withdrawn) The apparatus of claim 66 wherein the processor has been programmed to (i) calculate an optical response for a set of sample parameters, including overlay misalignment, (ii) compare the measured properties with the calculated optical response, and (iii) minimize the difference between the measured properties and the calculated optical response, wherein the calculation of an optical response is according to an optical model of the sample that accounts for the diffraction of electromagnetic waves by the pair of gratings of the metrology target and the interaction of the gratings with each other's diffracted field.

71. (Withdrawn) The apparatus of claim 70 wherein the processor has access to a pre-computed database from which at least a portion of the calculated optical response can be retrieved.

72. (Withdrawn) An apparatus for determining the overlay error comprising,
a metrology target comprising a first diffraction grating built into a patterned layer A and a second diffraction grating is built into a patterned layer B, where layers A and B are desired to be aligned with respect to each other, the two gratings substantially overlapping when viewed from a direction that is perpendicular to the layers A and B;
an ellipsometer that illuminates the metrology target and that measures properties of light that has interacted with the metrology target; and
a processor which estimates the offset of the grating pair from the pair's measured optical characteristics.

73. (Withdrawn) The apparatus of claim 72 wherein at least one of the two gratings contains more than one line per pitch, the widths of the at least two lines in each pitch (unit cell) being substantially different from each other.

74. (Withdrawn) The apparatus of claim 72 wherein at least one other layer of material separates layers A and B at the metrology target.

75. (Withdrawn) The apparatus of claim 72 wherein the ellipsometer measures properties of light that has interacted with the metrology target as a function of wavelength.

76. (Withdrawn) The apparatus of claim 72 wherein the processor has been programmed to (i) calculate an optical response for a set of sample parameters, including overlay misalignment, (ii) compare the measured properties with the calculated optical response, and (iii) minimize the difference between the measured properties and the calculated optical response, wherein the calculation of an optical response is according to an optical model of the sample that accounts for the diffraction of electromagnetic waves by the pair of gratings of the metrology target and the interaction of the gratings with each other's diffracted field.

77. (Withdrawn) The apparatus of claim 76 wherein the processor has access to a pre-computed database from which at least a portion of the calculated optical response can be retrieved.

78. (Previously presented) A method of obtaining overlay measurements for a semiconductor wafer, the method comprising:
forming a periodic grating on the wafer having:
a first set of gratings,
wherein the first set of gratings are formed on the wafer using a first mask, and
a second set of gratings,
wherein the second set of gratings are formed on the wafer using a second mask,
wherein the first and second sets of gratings are intended to be formed on the wafer with an intended asymmetrical alignment when the first mask and second mask are in alignment;
measuring a diffraction signal of the first and second sets of gratings after the first and second sets of gratings are formed on the wafer; and
determining a misalignment between the first and second sets of gratings formed on the wafer based on the measured diffraction signal.

79. (Previously presented) The method of claim 78, wherein the measured diffraction signal is a zero-order diffraction.

80. (Previously presented) The method of claim 79, wherein only the zero-order diffraction is measured.

81. (Previously presented) The method of claim 78, wherein the diffraction signal is measured using an optical metrology system.

82. (Previously presented) The method of claim 81, wherein the optical metrology system includes an ellipsometer.

83. (Previously presented) The method of claim 81, wherein the optical metrology system includes a reflectometer.

84. (Previously presented) The method of claim 78, wherein the diffraction signal is measured using an incident signal with a normal incidence angle.

85. (Previously presented) The method of claim 78, wherein the diffraction signal is measured using an incident signal with an oblique incidence angle.

86. (Previously presented) The method of claim 85, wherein the incident signal has an azimuthal angle of zero degrees.

87. (Previously presented) The method of claim 85, wherein measuring the diffraction signal includes:
measuring the amplitude of the diffraction signal.

88. (Previously presented) The method of claim 78 further comprising:
generating a set of diffraction signals for a range of possible misalignments between the first and second sets of gratings,
wherein each diffraction signal in the set corresponds to a different possible misalignment within the range of possible misalignments.

89. (Previously presented) The method of claim 88 further comprising:
generating a response curve of the correspondence between the different possible misalignments of the first and second sets of gratings and the set of diffraction signals.

90. (Previously presented) The method of claim 88 further comprising:
determining the intended asymmetric alignment between the first and second sets of gratings based on the generated set of diffraction signals and range of possible alignments.

91. (Previously presented) The method of claim 88, wherein the set of diffraction signals are generated empirically.

92. (Previously presented) The method of claim 88, wherein the set of diffraction signals are generated using modeling.

93. (Previously presented) The method of claim 88, wherein the determining the misalignment between the first and second sets of gratings comprises:
comparing the measured diffraction signal to the generated set of diffraction signals; and
determining the possible misalignment that corresponds to the diffraction signal from the generated set of diffraction signals that matches the measured diffraction signal.

94. (Previously presented) The method of claim 78,
wherein the first and second sets of gratings include a plurality of ridges that repeat at a periodic interval, and
wherein the ridges of the first and second sets of gratings alternate.

95. (Previously presented) The method of claim 94,
wherein the ridges of the first and second sets of gratings include centerlines having a spacing between the centerlines of the ridges of the first and second sets of gratings, and
wherein the first and second sets of gratings are symmetrically aligned when the spacing between the centerlines is uniform and asymmetrically aligned when the spacing between the centerlines is non-uniform.

96. (Previously presented)) The method of claim 95, wherein the intended asymmetric alignment includes an offset from symmetrical alignment of the first and second sets of gratings.

97. (Previously presented) The method of claim 78, wherein the first and second sets of gratings include a plurality of ridges that repeat at a periodic interval, and
wherein the ridges of the second set of gratings are formed on the ridges of the first set of gratings.

98. (Previously presented) The method of claim 97, wherein the ridges of the first and second sets of gratings include centerlines, and
wherein the first and second sets of gratings are symmetrically aligned when the centerlines of the ridges of the first and second sets of gratings are aligned and asymmetrically aligned when the centerlines are not aligned.

99. (Previously presented) The method of claim 98, wherein the intended asymmetric alignment includes an offset from symmetrical alignment of the first and second sets of gratings.

100. (Previously presented) The method of claim 78, wherein forming a periodic grating on the wafer comprises:
forming a periodic grating in a first metrology field on the wafer;
forming a periodic grating in a second metrology field on the wafer,
wherein the first and second metrology fields are separated by a distance on the wafer;
obtaining overlay measurements from the first and second metrology fields; and
computing an error based on the obtained overlay measurements.

101. (Previously presented) A method of obtaining overlay measurements for a semiconductor wafer using a periodic grating, the method comprising:
forming a first set of gratings of the periodic grating on the wafer;
forming a second set of gratings of the periodic grating on the wafer,

wherein the first and second sets of gratings are formed using separate masks, and
wherein the second set of gratings are intended to be formed on the wafer with an
intended asymmetrical alignment from the first set of gratings when the separate masks are in
alignment;

generating a set of diffraction signals for a range of possible misalignments between the
first and second sets of gratings,

wherein each of the diffraction signal in the generated set of diffraction signals
corresponds to a possible misalignment between the first and second sets of gratings;

measuring a diffraction signal of the first and second sets of gratings after the first and
second sets of gratings are formed on the wafer,

wherein the diffraction signal is measured; and

determining a misalignment between the first and second sets of gratings based on the
measured diffraction signal and the generated set of diffraction signals.

102. (Previously presented) The method of claim 101, wherein the determining the
misalignment between the first and second sets of gratings comprises:

comparing the measured diffraction signal to the generated set of diffraction signals; and

determining the possible misalignment that corresponds to the diffraction signal from the
generated set of diffraction signals that matches the measured diffraction signal.

103. (Previously presented) The method of claim 101, wherein the measured
diffraction signal is a zero-order diffraction.

104. (Previously presented) The method of claim 101 further comprising:

generating a plurality of sets of diffraction signals at various wavelengths and/or
polarizations.

105. (Previously presented) The method of claim 101,

wherein the first and second sets of gratings include a plurality of ridges that alternate
with a spacing between the ridges,

wherein the first and second sets of gratings are symmetrically aligned when the spacing between the ridges of the first and second sets of gratings is uniform and asymmetrically aligned when the spacing is non-uniform.

106. (Previously presented) The method of claim 101,
wherein the first and second sets of gratings include a plurality of ridges with centerlines,
wherein the ridges of the second set of gratings are formed on the ridges of the first set of gratings, and

wherein the first and second sets of gratings are symmetrically aligned when the centerlines of the ridges of the first and second sets of gratings are aligned and asymmetrically aligned when the centerlines are not aligned.

107. (Previously presented) A method of obtaining overlay measurements for a semiconductor wafer using a periodic grating formed on the wafer, the method comprising:
obtaining the wafer, wherein the period grating on the wafer comprises:
a first set of grating that were formed on the wafer using a first mask,
a second set of gratings that were formed on the wafer using a second mask,
wherein the first and second sets of gratings were intended to be formed on the wafer with an asymmetric alignment when the first mask and second mask are in alignment;
generating a set of diffraction signals for a plurality of possible misalignments between the first and second sets of gratings;
measuring a diffraction signal of the first and second sets of gratings from the obtained wafer,
wherein the diffraction signal is measured, and
wherein the measured diffraction signal is a zero-order diffraction;
comparing the measured diffraction signal to the generated set of diffraction signals; and
determining an amount and direction of misalignment between the first and second sets of gratings on the obtained wafer based on the possible alignment that corresponds to the diffraction signal from the set of diffraction signals that matches the measured diffraction signal.

108. (Previously presented) The method of claim 107,
wherein the periodic grating on the wafer further comprises:
a first periodic grating oriented for obtaining overlay measurements in a first coordinate
direction, and
a second periodic grating oriented for obtaining overlay measurements in a second
coordinate direction; and
wherein measuring a diffraction signal further comprises:
measuring a first diffraction signal from the first periodic grating, and
measuring a second diffraction signal from the second periodic grating without rotating
the wafer.

109. (Previously presented) The method of claim 108, wherein the measured
diffraction signals and the generated diffraction signals have amplitude ratios, and wherein the
amplitude ratios of the measured diffraction signals are compared with the amplitude ratios of
the generated diffraction signals.

110. (Previously presented) The method of claim 108, wherein the diffraction signals
are measured using an oblique and conical incident signal.

111. (Previously presented) The method of claim 107, wherein the diffraction signal
is measured using a normal incidence angle.

112. (Previously presented) The method of claim 107, wherein the diffraction signal
is measured using an oblique incidence angle with an azimuthal angle.

113. (Previously presented) The method of claim 107, wherein the diffraction signal
is measured using an oblique incidence angle with an azimuthal angle of zero degrees.

114. (Previously presented) The method of claim 107,
wherein the first and second sets of gratings include a plurality of ridges that alternate
with a spacing between the ridges,

wherein the first and second sets of gratings are symmetrically aligned when the spacing between the ridges of the first and second sets of gratings is uniform and asymmetrically aligned when the spacing is non-uniform.

115. (Previously presented) The method of claim 107,
wherein the first and second sets of gratings include a plurality of ridges with centerlines,
wherein the ridges of the second set of gratings are formed on the ridges of the first set of gratings, and

wherein the first and second sets of gratings are symmetrically aligned when the centerlines of the ridges of the first and second sets of gratings are aligned and asymmetrically aligned when the centerlines are not aligned.

116. (Previously presented) A system to obtain overlay measurements of a semiconductor wafer, the system comprising:

a periodic grating formed on the wafer comprising:

a first set of gratings formed using a first mask,

a second set of gratings formed using a second mask, and

wherein the first and second sets of gratings are intended to be formed with an asymmetric alignment when the first mask and second mask are in alignment; and

an optical metrology system comprising:

a detector configured to measure a diffraction signal from the first and second sets of gratings, and

a signal processing unit configured to determine a misalignment between the first and second sets of gratings based on the measured diffraction signal.

117. (Previously presented) The system of claim 116, wherein the signal processing unit is configured to compare the measured diffraction signal to a set of diffraction signals generated for a plurality of possible alignments between the first and second sets of gratings.

118. (Previously presented) The system of claim 116, wherein the periodic grating further comprises:

a first periodic grating oriented in a first coordinate direction; and
a second periodic grating oriented in a second coordinate direction,
wherein overlay measurements can be obtained in the first and second coordinate directions using the first and second periodic gratings without rotating the wafer.

119. (Previously presented) The system of claim 118, wherein the optical metrology system comprises:

a source configured to produce an oblique and conical incident signal.

120. (Previously presented) The system of claim 116, wherein the optical metrology system comprises:

a source configured to produce a normal incident signal.

121. (Previously presented) The system of claim 116, wherein the optical metrology system comprises:

a source configured to produce an incident signal having an oblique incidence angle and an azimuthal angle of zero degrees.

122. (Previously presented) The system of claim 116, wherein the periodic grating comprises:

a first portion with the first and second sets of gratings having a first alignment; and
a second portion with the first and second sets of gratings having a second alignment.

123. (Previously presented) The system of claim 122,
wherein the detector is configured to measure a first diffraction signal from the first portion of the periodic grating and a second diffraction signal from the second portion of the periodic grating, and

wherein the signal processor is configured to determine the amount and direction of misalignment between the first and second sets of gratings based on the measured first and second diffraction signals.

124. (Previously presented) The system of claim 123, wherein the signal processor is configured to determine the alignment of the first and second sets of gratings by comparing the difference between the measured first and second diffraction signals to a set of difference signals generated for a plurality of possible misalignments between the first and second sets of gratings.

125. (Previously presented) The system of claim 123, wherein the periodic grating further comprises:

- a third portion having only the first set of gratings; and
- a fourth portion having the second set of gratings.

126. (Previously presented) The system of claim 125, wherein the optical metrology system comprises:

- a library of simulated-diffraction signals having a set of theoretical geometry of the first and second sets of gratings;

- wherein the detector is configured to measure a diffraction signal from the third portion and a diffraction signal from the fourth portion; and

- wherein the signal processing unit is configured to compare the measured diffraction signal to the simulated-diffraction signals to determine the geometry of the first and second sets of gratings.

127. (Previously presented) The system of claim 116, wherein the first and second sets of gratings include a plurality of ridges that alternate with a spacing between the ridges; and wherein the first and second sets of gratings are symmetrically aligned when the spacing between the ridges of the first and second sets of gratings is uniform and asymmetrically aligned when the spacing is non-uniform.

128. (Previously presented) The system of claim 116, wherein the first and second sets of gratings include a plurality of ridges with centerlines; wherein the ridges of the second set of gratings are formed on the ridges of the first set of gratings; and wherein the first and second sets of gratings are symmetrically aligned when the centerlines of the ridges of the first and

second sets of gratings are aligned and asymmetrically aligned when the centerlines are not aligned.

129. (Previously presented) A method to obtain overlay measurements for a semiconductor wafer, comprising:

measuring a diffraction signal of a first set of grating and a second set of gratings of a periodic grating formed on the wafer, wherein

the first set of gratings were formed using a first mask,

the second set of gratings were formed using a second mask, and

wherein the first and second sets of gratings were intended to be formed on the wafer with an asymmetric alignment when the first mask and second mask are in alignment;

generating a set of diffraction signals for a plurality of possible misalignments between the first and second sets of gratings;

determining a misalignment of the first and second sets of gratings formed on the wafer based on the measured diffraction signal and the generated set of diffraction signals; and

130. (Previously presented) The method of claim 129, further comprising:
obtaining the geometry of the first set of gratings; and
obtaining the geometry of the second set of gratings,
wherein the generated set of diffraction signals is generated based on the obtained geometry of the first and second sets of gratings.

131. (Previously presented) The method of claim 130, further comprising:
measuring diffraction signals of the first set of gratings;
measuring diffraction signals of the second set of gratings; and
comparing the measured diffraction signals to a library of simulated-diffraction signals having a set of theoretical geometry of the first and second sets of gratings.

132. (Previously presented) The method of claim 131, wherein the diffraction signals of the first set of gratings are measured from a third portion of the grating having only the first

set of gratings, and the diffraction signals of the second set of gratings are measured from a fourth portion of the grating having the second set of gratings.

133. (Previously presented) The method of claim 129, further comprising:
measuring a first diffraction signal from a first periodic grating;
determining the amount and direction of misalignment between the first and second sets of gratings in a first coordinate direction using the first measured diffraction signal;
measuring a second diffraction signal from a second periodic grating without rotating the wafer; and
determining the amount and direction of misalignment between the first and second sets of gratings in a second coordinate direction using the second measured diffraction signal.

134. (Previously presented) A method of obtaining overlay measurements for a semiconductor wafer, the method comprising:
forming a periodic grating on the wafer having: a first set of gratings, wherein the first set of gratings are formed on the wafer using a first mask, and a second set of gratings, wherein the second set of gratings are formed on the wafer using a second mask;
obtaining zero-order diffracted radiation polarization measurements, of a portion of the periodic grating after forming the first and second sets of gratings; and
determining any overlay error between the first and second masks used to form the first and second sets of gratings based on the obtained polarization measurements.

135. (Previously presented) The method of claim 134, wherein said obtaining obtains zero-order diffracted radiation polarization measurements, with the analyzer polarization at a non-zero angle with respect to the polarizer polarization, of a portion of the periodic grating after forming the first and second sets of gratings.

136. (Previously presented) The method of claim 134, wherein said obtaining obtains zero-order diffracted radiation polarization measurements, when relative rotational motion is caused between the analyzer polarization and the polarizer polarization, of a portion of the periodic grating after forming the first and second sets of gratings.

137. (Previously presented) The method of claim 134, wherein obtaining zero-order polarization measurements comprises: obtaining a first zero-order polarization measurement; and obtaining a second zero-order polarization measurement, wherein the second zero-order polarization measurement has a polarization different from that of the first zero-order polarization measurement.

138. (Previously presented) The method of claim 137, wherein the first and second zero-order polarization measurements are obtained from the same site on the periodic grating.

139. (Previously presented) The method of claim 134, wherein said determining any overlay error comprises: comparing the zero-order polarization measurement to a reference signal.

140. (Previously presented) The method of claim 139, wherein the reference signal is generated using modeling.

141. (Previously presented) The method of claim 134 further comprising: obtaining a set of first zero-order polarization measurements for a range of possible misalignments between the first and second masks; and obtaining a set of second zero-order polarization measurements for a range of possible misalignments between the first and second masks.

142. (Previously presented) The method of claim 141 further comprising: generating a first response curve based on the set of first zero-order polarization measurements, wherein the first response curve characterizes a relationship between the different possible misalignments of the first and second masks and the set of first zero-order polarization measurements; and generating a second response curve based on the set of second zero-order polarization measurements, wherein the second response curve characterizes a relationship between the different possible misalignments of the first and second masks and the set of second zero-order polarization measurements.

143. (Previously presented) The method of claim 134, wherein the first zero-order polarization measurement includes TE polarization and the second zero-order polarization measurement includes TM polarization.

144. (Previously presented) The method of claim 134, wherein the first zero-order polarization measurement includes TM polarization and the second zero-order polarization measurement includes TE polarization.

145. (Previously presented) The method of claim 134, wherein the zero-order polarization measurements are obtained using an optical metrology system.

146. (Previously presented) The method of claim 145, wherein the optical metrology system includes a reflectometer or an ellipsometer.

147. (Previously presented) The method of claim 146, wherein the ellipsometer includes: a polarizer; and an analyzer, wherein the polarizer and the analyzer are set to a first angular setting to obtain a first zero-order polarization measurement, and wherein the polarizer and the analyzer are set to a second angular setting to obtain a second zero-order polarization measurement.

148. (Previously presented) The method of claim 134, wherein the first and second sets of gratings include a plurality of ridges that repeat at a periodic interval, and wherein the ridges of the first and second sets of gratings alternate.

149. (Previously presented) The method of claim 148, wherein the ridges of the first and second sets of grating having a spacing between them; and wherein the first and second sets of gratings are formed with the spacing between them uniform when the first and second masks are aligned without an overlay error.

150. (Previously presented) The method of claim 134, wherein the first and second sets of gratings include a plurality of ridges that repeat at a periodic interval, and wherein the ridges of the second set of gratings are formed on the ridges of the first set of gratings.

151. (Previously presented) The method of claim 150, wherein the ridges of the first and second sets of gratings include centerlines, and wherein the first and second sets of gratings are formed with the centerlines of the ridges aligned when the first and second masks are aligned without an overlay error.

152. (Previously presented) The method of claim 134, wherein the periodic grating is formed from isotropic materials.

153. (Previously presented) The method of claim 134, wherein the zero-order polarization measurements are obtained using an oblique incident signal.

154. (Previously presented) The method of claim 134, wherein the first and second sets of gratings are formed from different materials.

155. (Previously presented) The method of claim 134, wherein the first and second sets of gratings are formed from different materials and have different heights.

156. (Previously presented) The method of claim 134, wherein the first and second sets of gratings have different linewidths.

157. (Previously presented) A method of obtaining overlay measurements for a semiconductor wafer, the method comprising:

forming a periodic grating on the wafer having: a first set of periodic gratings, and a second set of periodic gratings, wherein the first and second sets of periodic gratings are formed using separate masks;

obtaining zero-order polarization measurements from the periodic grating after forming the first and second sets of gratings, wherein the zero-order polarization measurements are obtained using an oblique incident angle; and

determining any overlay error associated with the formation of the first and second sets of gratings based on the obtained zero-order polarization measurements.

158. (Previously presented) The method of claim 157, wherein obtaining zero-order polarization measurements comprises: obtaining a first zero-order polarization measurement; and obtaining a second zero-order polarization measurement, wherein the second zero-order polarization measurement has a polarization different from that of the first zero-order polarization measurement.

159. (Previously presented) The method of claim 157, wherein the first zero-order polarization measurement includes TE polarization and the second zero-order polarization measurement includes TM polarization.

160. (Previously presented) The method of claim 157, wherein the first zero-order polarization measurement includes TM polarization and the second zero-order polarization measurement includes TE polarization.

161. (Previously presented) The method of claim 157, wherein the first and second zero-order polarization measurements are obtained from a single site on the periodic grating.

162. (Previously presented) The method of claim 157 further comprising: obtaining a set of first zero-order polarization measurements for a range of possible misalignments between the first and second gratings; and obtaining a set of second zero-order polarization measurements for a range of possible misalignments between the first and second gratings.

163. (Previously presented) The method of claim 162 further comprising: generating a first response curve based on the set of first zero-order polarization measurements; and generating a second response curve based on the set of second zero-order polarization

measurements, wherein the first and second response curves characterize a relationship between the different possible misalignments of the first and second gratings and the zero-order polarization measurements.

164. (Previously presented) The method of claim 157, wherein the zero-order polarization measurements are obtained using an ellipsometer having: a polarizer; and an analyzer, wherein the polarizer and the analyzer are set to a first angular setting to obtain a first zero-order polarization measurement, and wherein the polarizer and the analyzer are set to a second angular setting to obtain a second zero-order polarization measurement.

165. (Previously presented) The method of claim 157, wherein the first and second sets of gratings include a plurality of ridges that repeat at a periodic interval, and wherein the ridges of the first and second sets of gratings alternate.

166. (Previously presented) The method of claim 165, wherein the ridges of the first and second sets of grating have a spacing between them; and wherein the first and second sets of gratings are formed with the spacing between them nonuniform when an overlay error exists.

167. (Previously presented) The method of claim 157, wherein the first and second sets of gratings include a plurality of ridges that repeat at a periodic interval, and wherein the ridges of the second set of gratings are formed on the ridges of the first set of gratings.

168. (Previously presented) The method of claim 167, wherein the ridges of the first and second sets of gratings include centerlines, and wherein the first and second sets of gratings are formed with the centerlines of the ridges misaligned when an overlay error exists.

169. (Previously presented) The method of claim 157, wherein the periodic grating is formed from isotropic materials.

170. (Previously presented) A method of obtaining overlay measurements for a semiconductor wafer having a periodic grating with a first set of gratings and a second set of gratings, the method comprising:

obtaining a first zero-order polarization measurement from the periodic grating;

obtaining a second zero-order polarization measurement from the periodic grating,

wherein the first and second zero-order polarization measurements are obtained using an oblique incident angle, wherein the first and second zero-order polarization measurements are obtained from a single site on the periodic grating, and wherein the second zero-order polarization measurement has a polarization different from that of the first zero-order polarization measurement; and

determining any overlay error associated with the formation of the first and second sets of gratings based on the obtained first and second zero-order polarization measurements.

171. (Previously presented) The method of claim 170, wherein the first zero-order polarization measurement includes TE polarization and the second zero-order polarization measurement includes TM polarization.

172. (Previously presented) The method of claim 170, wherein the first zero-order polarization measurement includes TM polarization and the second zero-order polarization measurement includes TE polarization.

173. (Previously presented) The method of claim 170, wherein the periodic grating is formed from isotropic materials.

174. (Previously presented) The method of claim 170 further comprising: obtaining a set of first zero-order polarization measurements for a range of possible misalignments between the first and second gratings; and obtaining a set of second zero-order polarization measurements for a range of possible misalignments between the first and second gratings.

175. (Previously presented) The method of claim 170 further comprising: generating a first response curve based on the set of first zero-order polarization measurements; and

generating a second response curve based on the set of second zero-order polarization measurements, wherein the first and second response curves characterize a relationship between the different possible misalignments of the first and second gratings and the zero-order polarization measurements.

176. (Previously presented) The method of claim 170, wherein the first and second zero-order polarization measurements are obtained using an ellipsometer having: a polarizer; and an analyzer, wherein the polarizer and the analyzer are set to a first angular setting to obtain the first zero-order polarization measurement, and wherein the polarizer and the analyzer are set to a second angular setting to obtain the second zero-order polarization measurement.

177. (Previously presented) A system to obtain overlay measurements of a semiconductor wafer, the system comprising:

- a periodic grating formed on the wafer comprising:

- a first set of gratings formed using a first mask,

- a second set of gratings formed using a second mask; and

- an optical metrology system configured to:

- obtain zero-order polarization measurements from the periodic grating after the first and second sets of gratings are formed on the wafer, and

- determine any overlay error between the first and second masks used to form the first and second sets of gratings based on the obtained zero-order polarization measurements.

178. (Previously presented) The system of claim 177, wherein the optical metrology system is configured to: obtain a first zero-order polarization measurement; and obtain a second zero-order polarization measurement, wherein the second zero-order polarization measurement has a polarization different from that of the first zero-order polarization measurement.

179. (Previously presented) The system of claim 177, wherein the first and second zero-order polarization measurements are obtained from the same site on the periodic grating.

180. (Previously presented) The system of claim 177, wherein the optical metrology system is configured to: compare the zero-order polarization measurements to a reference signal.

181. (Previously presented) The system of claim 177, wherein the first zero-order polarization measurement includes TE polarization and the second zero-order polarization measurement includes TM polarization.

182. (Previously presented) The system of claim 177, wherein the first zero-order polarization measurement includes TM polarization and the second zero-order polarization measurement includes TE polarization.

183. (Previously presented) The system of claim 177, wherein the optical metrology system includes a reflectometer or an ellipsometer.

184. (Previously presented) The system of claim 183, wherein the ellipsometer includes: a polarizer; and an analyzer, wherein the polarizer and the analyzer are set to a first angular setting to obtain a first zero-order polarization measurement, and wherein the polarizer and the analyzer are set to a second angular setting to obtain a second zero-order polarization measurement.

185. (Previously presented) The system of claim 177, wherein the first and second sets of gratings include a plurality of ridges that repeat at a periodic interval, and wherein the ridges of the first and second sets of gratings alternate.

186. (Previously presented) The system of claim 185, wherein the ridges of the first and second sets of grating have a spacing between them; and wherein the first and second sets of gratings are formed with the spacing between them uniform when the first and second masks are aligned without an overlay error.

187. (Previously presented) The system of claim 177, wherein the first and second sets of gratings include a plurality of ridges that repeat at a periodic interval, and wherein the ridges of the second set of gratings are formed on the ridges of the first set of gratings.

188. (Previously presented) The system of claim 187, wherein the ridges of the first and second sets of gratings include centerlines, and wherein the first and second sets of gratings are formed with the centerlines of the ridges aligned when the first and second masks are aligned without an overlay error.

189. (Previously presented) The system of claim 177, wherein the periodic grating is formed from isotropic materials.

190. (Previously presented) The system of claim 177, wherein the optical metrology system obtains the zero-order polarization measurements using an oblique incident signal.

191. (Previously presented) A system to obtain overlay measurements of a semiconductor wafer having a periodic grating with a first set of gratings and a second set of gratings, the system comprising: an optical metrology system configured to: obtain a first zero-order polarization measurement from a site on the periodic grating; obtain a second zero-order polarization measurement from the same site on the periodic grating as the first zero-order polarization measurement; and determine any overlay error associated with the formation of the first and second sets of gratings based on the obtained first and second zero-order polarization measurements.

192. (Previously presented) The system of claim 191, wherein the optical metrology system includes: a polarizer; and an analyzer, wherein the polarizer and the analyzer are set to a first angular setting to obtain the first zero-order polarization measurement, and wherein the polarizer and the analyzer are set to a second angular setting to obtain the second zero-order polarization measurement.

193. (Previously presented) The system of claim 191, wherein the optical metrology system is configured to: compare the first zero-order polarization measurement and the second zero-order polarization measurement to a reference signal to determine whether an overlay error exists.

194. (Previously presented) The system of claim 191, wherein the periodic grating is formed from isotropic materials.

195. (Previously presented) The system of claim 191, wherein the optical metrology system obtains the zero-order polarization measurements using an oblique incident signal.

196. (Previously presented) The system of claim 191, wherein the second zero-order polarization measurement is obtained with the analyzer polarization different from the polarizer polarization.

197. (Previously presented) A device containing computer executable instructions for causing a computer to obtain overlay measurements for a semiconductor wafer, comprising instructions for: obtaining zero-order polarization measurements from a periodic grating formed on the wafer, wherein a first set of gratings of the periodic grating are formed on the wafer using a first mask, and wherein a second set of gratings of the periodic grating are formed on the wafer using a second mask; and determining any overlay error between the first mask and the second mask used to form the first and second sets of gratings based on the obtained zero-order polarization measurements.

198. (Previously presented) The device of claim 197, wherein obtaining zero-order polarization measurements comprises: obtaining a first zero-order polarization measurement; and obtaining a second zero-order polarization measurement, wherein the second zero-order polarization measurement has a polarization different from that of the first zero-order polarization measurement.

199. (Previously presented) The device of claim 197, wherein determining any overlay error comprises: comparing the zero-order polarization measurements to a reference signal.

200. (Previously presented) The device of claim 197, said instructions further comprising: obtaining a set of first zero-order polarization measurements for a range of possible misalignments between the first and second masks; and obtaining a set of second zero-order polarization measurements for a range of possible misalignments between the first and second masks.

201. (Previously presented) The device of claim 200 said instructions further comprising: generating a first response curve based on the set of first zero-order polarization measurements, wherein the first response curve characterizes a relationship between the different possible misalignments of the first and second masks and the set of first zero-order polarization measurements; and generating a second response curve based on the set of second zero-order polarization measurements, wherein the second response curve characterizes a relationship between the different possible misalignments of the first and second masks and the set of second zero-order polarization measurements.

202. (Previously presented) The device of claim 197, wherein the first zero-order polarization measurement includes TE polarization and the second zero-order polarization measurement includes TM polarization.

203. (Previously presented) The device of claim 197, wherein the first zero-order polarization measurement includes TM polarization and the second zero-order polarization measurement includes TE polarization.

204. (Previously presented) The device of claim 197, wherein the first and second zero-order polarization measurements are obtained from a single site on the periodic grating.

205. (New) A method of obtaining overlay measurements, the method comprising:
forming a first grating test pattern using a first layer mask;
forming a second grating test pattern using a second layer mask,
wherein the first and second grating test patterns have the same periodicity;
measuring the first and second grating test patterns using an optical metrology
equipment; and

measuring the alignment of the second layer mask to the first layer mask based on the
measurement of the first and second grating test patterns.

206. (New) The method of claim 205, wherein grating lines of the second grating test
pattern are formed on top of grating lines of the first grating test pattern.

207. (New) The method of claim 206, wherein a first distance measures a gap from a
left edge of a first grating line of the first grating test pattern to a left edge of a first grating line
of the second grating test pattern, wherein the first grating line of the second grating test pattern
is formed on top of the first grating line of the first grating test pattern.

208. (New) The method of claim 207, wherein a second distance measures a gap from
the right edge of the first grating line of the first grating test pattern to the right edge of the first
grating line of the second grating test pattern.

209. (New) The method of claim 206, further comprising:
forming one or more material layers between the first grating test pattern and the second
grating test pattern.

210. (New) The method of claim 205, wherein grating lines of the second grating test
pattern are interlaced with grating lines of the first grating test pattern.

211. (New) The method of claim 210, wherein a first distance measures a gap from a
right edge of a first grating line of the first grating test pattern to a left edge of a first grating line

of the second grating test pattern, wherein the first grating line of the second grating test pattern is formed adjacent to the first grating line of the first grating test pattern.

212. (New) The method of claim 211, wherein a second distance measures a gap from a right edge of the first grating line of the second grating test pattern to a left edge of a second grating line of the first grating test pattern, wherein the first grating line of the second grating test pattern is formed between the first and second grating lines of the first grating test pattern.

213. (New) The method of claim 210, further comprising:
forming one or more material layers between the first grating test pattern and the second grating test pattern.

214. (New) The method of claim 205, wherein the first and second grating test patterns include:

- a first grating having grating lines in a first orientation; and
- a second grating having grating lines in a second orientation perpendicular to the first orientation, wherein the second grating is adjacent to the first grating.

215. (New) The method of claim 214, wherein the first and second grating test patterns include:

- a third grating having grating lines in a third orientation, wherein the third orientation is 45 degrees relative to the first orientation; and
- a fourth grating having grating lines in a fourth orientation perpendicular to the third orientation, wherein the fourth grating is adjacent to the third grating and the second grating.

216. (New) The method of claim 215, wherein the first, second, third, and fourth gratings are quadrants in a four-quadrant test pattern formed on a semiconductor wafer.

217. (New) The method of claim 216, wherein measuring the first and second grating test patterns comprises:

measuring the first, second, third, and fourth gratings without rotating or reloading the semiconductor wafer.

218. (New) The method of claim 217, wherein measuring the alignment of the second layer mask to the first layer mask comprises:

measuring the alignment in the first, second, third, and fourth orientations based on the measurement of the first, second, third, and fourth gratings.

219. (New) The method of claim 205, wherein the optical metrology equipment is a spectroscopic reflectometer or a spectroscopic ellipsometer.

220. (New) A method of obtaining overlay measurements, the method comprising:
forming a first grating test pattern using a first layer mask;
forming a second grating test pattern using a second layer mask,
wherein the first and second grating test patterns have the same periodicity, and wherein the first and second grating test patterns have:

a first grating having grating lines in a first orientation, and

a second grating having grating lines in a second orientation perpendicular to the first orientation;

measuring the first and second grating patterns including the first and second gratings using an optical metrology equipment; and

measuring the alignment of the second layer mask to the first layer mask in the first and second orientations based on the measurement of the first and second grating patterns including the first and second gratings.

221. (New) The method of claim 220, wherein a first distance measures a gap from a left edge of a first grating line of the first grating test pattern to a left edge of a first grating line of the second grating test pattern, wherein the first grating line of the first grating test pattern is formed on top of the first grating line of the second grating test pattern, and wherein a second distance measures a gap from the right edge of the first grating line of the first grating test pattern to the right edge of the first grating line of the second grating test pattern.

222. (New) The method of claim 220, wherein a first distance measures a gap from a right edge of a first grating line of the first grating test pattern to a left edge of a first grating line of the second grating test pattern, wherein the first grating line of the second grating test pattern is formed adjacent to the first grating line of the first grating test pattern, wherein a second distance measures a gap from a right edge of the first grating line of the second grating test pattern to a left edge of a second grating line of the first grating test pattern, and wherein the first grating line of the second grating test pattern is formed between the first and second grating lines of the first grating test pattern.

223. (New) The method of claim 220, wherein the first and second gratings are formed on a semiconductor wafer, and wherein the first and second gratings are measured using the optical metrology equipment without reloading the semiconductor wafer.

224. (New) The method of claim 220, wherein the first and second grating test patterns include:

a third grating having grating lines in a third orientation, wherein the third orientation is 45 degrees relative to the first orientation; and

a fourth grating having grating lines in a fourth orientation perpendicular to the third orientation.

225. (New) A structure formed on a semiconductor wafer for obtaining overlay measurements, the structure comprising:

a first grating test pattern formed on the semiconductor wafer using a first layer mask;
and

a second grating test pattern formed on the semiconductor wafer using a second layer mask,

wherein the first and second grating test patterns have the same periodicity,
wherein the first and second grating test patterns are measured using an optical metrology equipment, and

wherein the alignment of the second layer mask to the first layer mask is measured based on the measurement of the first and second grating test patterns.

226. (New) The structure of claim 225, wherein grating lines of the second grating test pattern are formed on top of grating lines of the first grating test pattern.

227. (New) The structure of claim 226, further comprising:

a first gap from a left edge of a first grating line of the first grating test pattern to a left edge of a first grating line of the second grating test pattern, wherein the first grating line of the second grating test pattern is formed on top of the first grating line of the first grating test pattern; and

a second gap from the right edge of the first grating line of the first grating test pattern to the right edge of the first grating line of the second grating test pattern.

228. (New) The structure of claim 226, further comprising:

one or more material layers formed between the first grating test pattern and the second grating test pattern.

229. (New) The structure of claim 225, wherein grating lines of the second grating test pattern are interlaced with grating lines of the first grating test pattern.

230. (New) The structure of claim 229, further comprising:

a first gap from a right edge of a first grating line of the first grating test pattern to a left edge of a first grating line of the second grating test pattern, wherein the first grating line of the second grating test pattern is formed adjacent to the first grating line of the first grating test pattern; and

a second gap from a right edge of the first grating line of the second grating test pattern to a left edge of a second grating line of the first grating test pattern, wherein the first grating line of the second grating test pattern is formed between the first and second grating lines of the first grating test pattern.

231. (New) The structure of claim 229, further comprising:
one or more material layers formed between the first grating test pattern and the second grating test pattern.

232. (New) The structure of claim 225, wherein the first and second grating test patterns include:

- a first grating having grating lines in a first orientation; and
- a second grating having grating lines in a second orientation perpendicular to the first orientation, wherein the second grating is adjacent to the first grating.

233. (New) The structure of claim 232, wherein the first and second grating test patterns include:

- a third grating having grating lines in a third orientation, wherein the third orientation is 45 degrees relative to the first orientation; and
- a fourth grating having grating lines in a fourth orientation perpendicular to the third orientation, wherein the fourth grating is adjacent to the third grating and the second grating.

234. (New) The structure of claim 233, wherein the first, second, third, and fourth gratings are quadrants in a four-quadrant test pattern formed on the semiconductor wafer.

235. (New) The structure of claim 225, wherein the optical metrology equipment is a spectroscopic reflectometer or a spectroscopic ellipsometer.

236. (New) A method of obtaining periodic structure overlay measurements, the method comprising:

- forming a first periodic structure using a first layer mask;
- forming a second periodic structure using a second layer mask,
- wherein the first and second periodic structures have the same pitch;
- measuring the first and second periodic structures using an optical metrology equipment;
- and

measuring the alignment of the second layer mask to the first layer mask based on the measurement of the first and second periodic structures.

237. (New) The method of claim 236, wherein grating lines of the second periodic structure are formed on top of grating lines of the first periodic structure.

238. (New) The method of claim 237, wherein a first distance measures a gap from a left edge of a first grating line of the first periodic structure to a left edge of a first grating line of the second periodic structure, wherein the first grating line of the second periodic structure is formed on top of the first grating line of the first periodic structure.

239. (New) The method of claim 238, wherein a second distance measures a gap from a right edge of the first grating line of the first periodic structure to a right edge of the first grating line of the second periodic structure.

240. (New) The method of claim 237, further comprising:
forming one or more material layers between the first periodic structure and the second periodic structure.

241. (New) The method of claim 236, wherein grating lines of the second periodic structure are interlaced with grating lines of the first periodic structure.

242. (New) The method of claim 241, wherein a first distance measures a gap from a right edge of a first grating line of the first periodic structure to a left edge of a first grating line of the second periodic structure, wherein the first grating line of the second periodic structure is formed adjacent to the first grating line of the first periodic structure.

243. (New) The method of claim 242, wherein a second distance measures a gap from a right edge of the first grating line of the second periodic structure to a left edge of a second grating line of the first periodic structure, wherein the first grating line of the second periodic structure is formed between the first and second grating lines of the first periodic structure.

244. (New) The method of claim 241, further comprising:
forming one or more material layers between the first periodic structure and the second periodic structure.

245. (New) The method of claim 236, wherein the first and second periodic structures include:

a first grating set having grating lines set in a first orientation; and
a second grating set having grating lines set in a second orientation perpendicular to the first orientation, wherein the second grating set is adjacent to the first grating set.

246. (New) The method of claim 236, wherein the optical metrology equipment is a spectroscopic reflectometer or a spectroscopic ellipsometer.

247. (New) A method of obtaining overlay measurements, the method comprising:
forming a first periodic structure using a first layer mask;
forming a second periodic structure using a second layer mask,
wherein the first and second periodic structures have the same pitch, and wherein the first and second periodic structures have:

a first grating set having grating lines set in a first orientation, and
a second grating set having grating lines set in a second orientation perpendicular to the first orientation;
measuring the first and second periodic structures including the first and second grating sets using an optical metrology equipment; and
measuring the alignment of the second layer mask to the first layer mask in the first and second orientations based on the measurement of the first and second periodic structures including the first and second grating sets.

248. (New) The method of claim 247, wherein a first distance measures a gap from a left edge of a first grating line of the first periodic structure to a left edge of a first grating line of the second periodic structure, wherein the first grating line of the first periodic structure is

formed on top of the first grating line of the second periodic structure, and wherein a second distance measures a gap from a right edge of the first grating line of the first periodic structure to a right edge of the first grating line of the second periodic structure.

249. (New) The method of claim 247, wherein a first distance measures a gap from a right edge of a first grating line of the first periodic structure to a left edge of a first grating line of the second periodic structure, wherein the first grating line of the second periodic structure is formed adjacent to the first grating line of the first periodic structure, wherein a second distance measures a gap from a right edge of the first grating line of the second periodic structure to a left edge of a second grating line of the first periodic structure, and wherein the first grating line of the second periodic structure is formed between the first and second grating lines of the first periodic structure.

250. (New) The method of claim 247 therein the first and second periodic structures are formed on a semiconductor wafer, and wherein the first and second periodic structures are measured using the optical metrology equipment without reloading the semiconductor wafer.

251. (New) A structure formed on a semiconductor wafer for obtaining overlay measurements, the structure comprising:

a first periodic structure formed on the semiconductor wafer using a first layer mask; and
a second periodic structure formed on the semiconductor wafer using a second layer mask,

wherein the first and second periodic structures have the same pitch,
wherein the first and second periodic structures are measured using an optical metrology equipment, and

wherein the alignment of the second layer mask to the first layer mask is measured based on the measurement of the first and second periodic structures.

252. (New) The structure of claim 251, wherein grating lines of the second periodic structure are formed on top of grating lines of the first periodic structure.

253. (New) The structure of claim 252, further comprising:

a first gap from a left edge of a first grating of the first periodic structure to a left edge of a first grating line of the second periodic structure, wherein the first grating line of the second periodic structure is formed on top of the first grating line of the first periodic structure; and

a second gap from a right edge of the first grating line of the first periodic structure to a right edge of the first grating line of the second periodic structure.

254. (New) The structure of claim 252, further comprising:

one or more material layers formed between the first periodic structure and the second periodic structure.

255. (New) The structure of claim 251, wherein grating lines of the second periodic structure are interlaced with grating lines of the first periodic structure.

256. (New) The structure of claim 255, further comprising:

a first gap from a right edge of a first grating line of the first periodic structure to a left edge of a first grating line of the second periodic structure, wherein the first grating line of the second periodic structure is formed adjacent to the first grating line of the first periodic structure; and

a second gap from a right edge of the first grating line of the second periodic structure to a left edge of a second grating line of the first periodic structure, wherein the first grating line of the second periodic structure is formed between the first and second grating lines of the first periodic structure.

257. (New) The structure of claim 255, further comprising:

one or more material layers formed between the first periodic structure and the second periodic structure.

258. (New) The structure of claim 251, wherein the first and second periodic structures include:

a first grating set having grating lines set in a first orientation; and

a second grating set having grating lines set in a second orientation perpendicular to the first orientation, wherein the second grating set is adjacent to the first grating set.

259. (New) The structure of claim 251, wherein the optical metrology equipment is a spectroscopic reflectometer or a spectroscopic ellipsometer.